An Approach to Operation of a Regional Primary Water Control System

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INTRODUCTION

The area encompassed within the Central and Southern Florida Flood Control District lies entirely within the State of Florida. From that circumstance, then, it is obvious that it does not have the interstate character of perhaps more typical regional water resource management agencies, such as the Delaware River Authority. Nevertheless, the area served by the District's works can be considered as a region. All, or parts, of several major watersheds lie within District boundaries. The full range of land usage from the wilderness of the Everglades to the urban sprawl of Metropolitan Miami is present. A wide variety of competing interests concerned with water and water-related land use exert their pressures on management. There is a broad array of local, State and national governmental agencies which become involved in management decisions. All of these factors tend to confirm the District as a regional rather than a local management agency. And yet, despite this at times bewildering physical, political and institutional variety, there is still a high degree of socio-economic unity in the area served. This, too, is a rather necessary hallmark of regionality.

The Flood Control District is an agency of the State of Florida. Created by statute in 1949, its function is to serve as the State's

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agent in meeting the local cooperation requirements set by the Congress under the several authorizations related to the Central and Southern Florida Flood Control Project. Construction, planned and designed by the Corps of Engineers and the District, and supervised by the Corps, is funded by the national and State governments. Other obligations are largely discharged through use of funds derived from an ad valorem tax levied throughout the District's eighteen counties, although there is some use of monies from the State's general revenue for certain types of land acquisition. Operation and maintenance of the completed system, with two exceptions, is the responsibility of the Flood Control District. These costs, and all other management costs, are wholly supported by the District-wide ad valorem tax.

DESCRIPTION OF WORKS

The major natural drainage areas within the more than 16,000 square mile District are the Kissimmee River - Lake Okeechobee - Everglades system, the upper third of the St. Johns River system, and the lower east coast drainage. To a large extent the works of the Central and Southern Florida Project have been superimposed on facilities which had been previously constructed by private interests and governmental agencies. Thus, in the Kissimmee River watershed the Project expanded upon Hamilton Diston's drainage works of the 1880's; south of Lake Okeechobee the Project enlarged and reworked the channels built by the Everglades Drainage District in the first quarter of this century; and in the east coastal area from Fort Pierce south various drainage canals, the majority originally constructed by local drainage districts, were incorporated in and improved by the Project.

Coming directly as a result of the severe wet hurricanes of 1947, the Central and Southern Florida Project's emphasis was understandably on flood control. And because of the nature of southeast Florida's topography, flood control necessarily implied major drainage improvements. But the experience of the previous twenty-five years with programs almost exclusively oriented to drainage indicated to Project planners the necessity for providing features which would prevent over-drainage and permit the capture and storage of some surplus surface waters. Consequently, even though major Project works were grafted onto already existing drainage systems, modifications and additions were made to achieve certain objectives in terms of water storage and conservation. Hence, certain major features of the Project such as the development of additional storage capacity in Lake Okeechobee, the creation of the 1300 square mile Everglades Water Conservation areas, and the provision of upland storage areas and valley reservoir-floodways in the upper St. Johns River Basin.

Important water conservation objectives, particularly from the standpoint of arresting over-drainage, were to be achieved by the works of the original comprehensive plan of 1947, authorized in 1948 and 1954. From the vantage point of hindsight, however, it was seen a few years ago that these works were, at best, in the nature of mitigating features only. They permitted perhaps a "holding of the line" at some point between the critical and the disastrous. In positive terms of provision and delivery of water supplies to meet the requirements of a growing urban population, an expanding agriculture, the Everglades National Park, and a developing recreational demand they were inadequate. Accordingly, a Project review for water supply was undertaken and in 1968 the Congress authorized construction of an $80 million addition to the Project. This water supply plan addresses itself to the twin problems of capture and storage of additional quantities of surplus surface waters and their delivery to points of need, but is limited to that portion of the Project area south and east of Lake Okeechobee.

As of this date the major works of the first authorizations in the Kissimmee River valley, the Everglades agricultural and water conservation areas, and the lower east coast area are completed and operational. At many locations in these areas the District has had as much as fifteen years of operational experience and at most locations no less than five years. Work around Lake Okeechobee and its outlets will be completed on a schedule which will permit it to be regulated at the higher levels of the original authorization in less than two years. Construction in the upper St. Johns River valley is about 30% completed, with some facilities already operational. Certain elements of the "water supply plan" are to be placed under contract within the next two to three years.

THE FUNCTION OF OPERATIONS & MANAGEMENT

Despite the newer concern with water supply, as expressed by the authorization of the "water supply plan", it must be remembered that the essential framework with which District management must work is a system designed originally on the basis of flood control considerations. A system superimposed on earlier drainage systems, and which has had integrated with it various water conservation features in the form of "on line" reservoirs. This is something which the Flood Control District must remember and, as the agency responsible for operation and management, cannot afford to forget. In simple terms we have a physical system the location and form of which was dictated by considerations which were of paramount importance 50 and 25 years ago. These are still important but they must now share this status with other considerations which have come to the fore as a result of local, regional and national social and economic changes. Revisions to the location and form of the physical system cannot readily be made, not only because of the major investment of public funds the system in being represents, but because of constraints on new construction now rightly being imposed by environmental considerations. The approach to the challenge of new values, new needs, new constraints, lies then in our case, in operations and management. In short we must get the maximum benefit and the optimal distribution of benefits out of the physical system we have. The District is working on the premise that with intelligent and imaginative operation and management this system has the capability of satisfying to a high degree the needs of the region it serves.

Operations, defined herein as the day-to-day manipulation of discrete quantities of water and management, defined as a longer-range water use strategy, are aspects of the same function. They are the end products of the decision-making activity. There have been no revolutions affecting the accepted concept of the elements required for rational decision-making. Essential information still must be collected and processed by some means. Alternative choices of action, if any, must be evaluated in terms of capabilities and analyzed as to consequences. Finally, a choice having been made, the decision must be implemented. No, there have been no revolutions in the logic of the decision-making function; but advances have been made in the development and application of certain tools which can be of immeasurable assistance to decision makers. More importantly, perhaps, there has been a conceptual revolution of sorts in which acceptance is being gained for the application of systems analysis techniques to water resource programs.

The District's approach to operation and management of its primary water control system takes cognizance of these changes. It also takes cognizance of the fact that we must deal with a physical system in being, not with one still on the drawing boards. This approach has only recently started to take on definite shape. Portions of it may, in the final event, be discarded, re-worked, modified or deferred for any number of valid reasons. As discussed herein, however, it represents our current thinking concerning the constitution of an integrated management system for making and implementing operations and management decisions within a context of increasing and changing water demand.

The approach being taken by the District involves the following:

1. Development and placement into operation of mathematical models of major discrete elements of the total physical system.
2. Research into, and development of, a mechanism for optimizing operational and management decisions.
3. Development and implementation of a communications and supervisory control system.

4. Definition of those constraints, operative presently and in the foreseeable future, which act to limit operational and management choices.

There is a good deal of overlap between these four areas of major activity. This, of course, is as it should be since together they should reflect the desired integrated approach to a solution of the District's specific operations and management problem. However, they will be discussed under separate headings in which the tie-ins with other activities will be indicated.

MATHEMATICAL MODELING

The District took its first steps toward developing a new approach to operations when it investigated the possibility of adapting mathematical modeling techniques to its system. Nowhere was the flood control orientation of this system more apparent than in the operation of Project reservoirs. The numerous lakes of the upper Kissimmee Basin, Lake Okeechobee, the Everglades Water Conservation Areas, and the planned upland and valley reservoirs of the St. Johns Valley all were, and are, operated on a fixed seasonal rule curve. These all require that a prescribed amount of flood storage space be available in each reservoir, each and every year, in the two or three month period preceding October 1. This general concept had been a source of dissatisfaction to the District's engineers for several years. Mathematical modeling was seen as a tool which, if properly applied, would permit a much greater flexibility in reservoir operations and provide a basis for rational longer-range management policies, thus producing a wider range of water-based benefits. Accordingly, in early 1968 a model development program was initiated in-house. In short, the District undertook an approach based on the concept expressed by John T. Mitchell, Jr., (1) in the context of operations rules, that "it is no longer feasible to insure accomplishment of a specific purpose by an inefficient over-design or blanketing approach which might lessen capability to serve other purposes."

The District's efforts in physical system modeling have been reported by Lalit K. Sinha (2) and by Lalit K. Sinha and Lennart E. Lindahl (3). The program was undertaken as a piece of research and development but, quite frankly, with the expectation of practical application in the operational situation in the Kissimmee Basin. An essential proviso of our decision was that model development would be performed by staff, not by consultants. We are approximately six months behind our initial schedule for operational testing of our first model. However, this is not deemed to be critical. A great deal of experience has been gained and a vast fund of knowledge in terms of hydrologic and hydraulic responses, mathematical relationships, programming techniques, and computer capabilities, has been amassed. We are convinced that this tool will work for us and that it will have application in one form or another in other major Project systems.

OPTIMIZATION OF OPERATIONS

The District's first thinking in the area of optimizing operations was, naturally, closely associated with the total concept of mathematical modeling. A three-pronged research and development approach was visualized; physical system model, prediction model, and optimization model. Physical system modeling was attacked first because of its primary importance and because of limitations in staff capability.

Further thinking in regard to optimization revived an earlier staff concept which had been shelved due to the lack of a suitable framework within which it could be further developed. Water stored within the Project area is a free good. It is delivered to the primary user, whether agricultural operator, municipality, or Everglades National Park, at no direct cost to him. There is no charge for water nor is there even a connection fee. The District has the responsibility for allocation of water, however, and certain physical and institutional means are available for the discharge of this responsibility. In considering this allocation problem it had occurred to us that, even in the absence of market control of water use, the economics of water use could be used as a guide for allocation policies and decisions. In other words, water allocation could be optimized to some extent on the basis of economic factors; that is, the value of water related to specific use, including flood control, in location and time. This concept found a home within the framework of an optimization, or allocation, model.

Working through the Water Resources Research Center at the University of Florida, the District in association with the School of Agriculture, worked up a research program for development of an economic model of a portion of the Kissimmee River system. A grant under Section 101 of Public Law 88-379 was made in July, 1969 by the Office of Water Resources Research. The program is under the direction of Dr. John Reynolds of the University of Florida. We made certain, however, that the program was written in such manner as to require intimate involvement of District staff in all aspects of the project.

This project has been described by Dr. Reynolds (4). Briefly, the work is being undertaken in two phases. The first phase treats a portion of the upper Kissimmee River Basin as a single basin in order to develop the basic inter-relationships between the various economic factors and water supply allocation. The second phase will treat the basin as a series of sub-basins and develop the additional complexities of allocations over space as well as time.

This is a pilot study only, its major purpose being, insofar as the District is concerned, to demonstrate the feasibility, or lack of feasibility, of using a programming model to develop longer-range operational strategies and management policies. Even if feasibility for more or less immediate application is not demonstrated it will most certainly point up areas of inadequacy of present institutional means for controlling optimal allocation of the water resource. It therefore represents a very necessary piece of research required for a more complete understanding of certain relationships governing consumptive and non-consumptive use of water.

Intimately associated with the optimization model is the prediction model. If the optimization model is to be used for developing longer-range strategies and policies, then it would be most useful to have long-range estimates of rainfall within reasonable limits of confidence. Some detailed statistical analyses of rainfall have been made by the District, as a start on this aspect of the optimization problem. It is not particularly difficult to adapt any of several models to generate reasonable rainfall records in terms of monthly or annual amounts. These models are usually based on the mean and the standard deviation in conjunction with other parameters, all derived from the historical record. Unfortunately, although these methods provide appropriate totals and an appropriate number of events of any given magnitude, they tend to ignore the order in which events occur, or rather to assume that they occur randomly. This assumption usually presents no problem when rainfalls are aggregated into totals covering a considerable period of time. But, as the time period is reduced, as is required in operational schemes, the order in which events occur becomes an important consideration. We have not yet succeeded in generating the patterns typical of various storm types on a continuing basis.

COMMUNICATIONS AND SUPERVISORY CONTROL

There are some 160 decision-making points within the District's physical system as now planned. These are the major water level control structures, pumping stations, and reservoir outlet structures. At these locations information such as upstream and downstream stage, number of gates open, amount of gate opening, number of pumps running, and engine RPM's is required for operation decision-making. In addition to these there are perhaps another 35 locations within the network of channels and reservoirs at which water level information should be procured in order to permit effective operations decisions to be made.

At present this type of information, plus rainfall data, is observed by conventional means and reported on a twice-daily basis, under non-emergency conditions, by voice communication on a radio network. Operations decisions are made at the central headquarters and appropriate instructions are relayed back by radio to dispersed field station sites, each of which is responsible for physical operations in a specifically defined area. Incoming "state of the system" data as well as outgoing operations instructions are logged on appropriate forms.

Hydrologic and meteorologic information is currently being collected mainly for historical purposes and secondarily for analysis of system design and operation. Both surface and groundwater stage data and rainfall data is collected by means of continuous recorders. This data collection program is design-oriented rather than operations-oriented. The information so collected plays no part in the operations decision-making activity.

Finally, at certain locations along the lower east coast water quality considerations may at times dictate a particular operational decision. Here, where salt water intrusion poses a threat to the groundwater, canal water salinities are routinely monitored, reported and logged by conventional means. Operational decisions concerning flushing of these waterways are based on these data together with consideration of the availability of fresh water for this purpose.

This system for the collection and transmission of information concerning the state of the physical system, the communication and implementation of operations decisions, and the recording of both incoming data and outgoing instructions is cumbersome. But despite this, if the District must continue to operate its facilities in the future in the fashion they are now being operated, this system with only minor modifications will be adequate. The reason for this statement becomes apparent when it is noted that the system described makes no mention of processing incoming data, evaluating physical system capabilities, examining alternative choices, or determining the consequences of any particular decision. Present operational procedures are largely governed by fixed rule. Operations decisions are predetermined and consequently there is essentially no choice other than that fixed by the date on the calendar. In these circumstances a relatively unsophisticated communications network will serve quite well to operate and manage such a rigidly constrained physical system.

However, having made a decision to attempt to achieve greater operational flexibility through the use of modeling techniques it became necessary for the District to re-evaluate its communications system. L. E. Lindahl and R. L. Hamrick (5) have discussed the question of support systems for watershed models and the trade-offs involved in their paper on "The Potential and Practicality of Watershed Models in Operational Water Management." Further development of the views expressed in that paper in the context of the District's objective of a real-time model configuration has indicated the need for a rather sophisticated support system.

A maximum system might involve the collection of data at some 300 sites; the 195 "in system" sites indicated earlier plus an additional 105 sites distributed over the Project area. Data collected would be that now collected by conventional means plus water quality and meteorologic data at selected locations. The system would require a highly reliable communications backbone and a real-time process control computer for data processing, storage and retrieval and for model execution. Display capabilities might be required in such a maximum system and supervisory control, either by operator or computer, would be necessary.

In line with this general thinking the District has solicited proposals for a systems analysis the purpose of which is to obtain an evaluation of its communications and supervisory control requirements. The recommendations forthcoming from this study will form the basis for a system which the District would intend to procure and install within a maximum period of eight years.

DEFINITION OF CONSTRAINTS

Because the District is dealing with an operational and management problem rather than a design problem, it is obvious that the first constraint to be considered is that of the physical system of works itself. The constraints exercised by channel, spillway, pumping station and reservoir capacities are, in our case, "given." Beyond this, since our management objective is to achieve maximum benefits from the given system, the District's working premise is that all other constraints now operative are subject to review, re-evaluation and possible change. An example, of course, is the approach being taken to achieve greater flexibility in the reservoir operation rules.

Constraints can be generally classified as being either physical or institutional. For our purposes institutional constraints are defined as only those which are formalized in the shape of the rules and regulations of regulatory agencies, the statutes of local State and national governments, or decisions of the courts. It might be simpler to define the former as natural constraints and the latter as man-made, but this would be an over-simplification and an inaccurate one. For example, it might be physically possible to store water at an elevation one foot higher in one of the District's Everglades Water Conservation Areas. This, however, might result in wide-spread and major changes in the Everglades environment. Public outcry against such environmental damage might make it impossible to take an action which would be quite feasible from a physical standpoint alone. This would then be a "man-made" constraint, but it would not be a constraint exercised as a result of application of a formal rule, regulation or statute. By our definition, therefore, it would not be an institutional constraint.

In addressing ourselves to the question of physical constraints, as broadly defined herein, the problem has appeared to be largely that of relating various changes in water conditions to effects on the environment and in evaluating society's probable perception of, and response to, these environmental effects. On the basis of this assessment of the problem the District has undertaken a number of environmental studies. Now under way are "base-line" investigations in Lake Okeechobee, the St. Johns River Basin, and the Everglades Water Conservation Areas. Evaluation of the results of these investigations is expected to indicate the trend of possible changes in the environment under varying water conditions. The necessity for continued monitoring and surveillance of environmental changes, if any, will be indicated. It is hoped that the net result will be to provide a set of operations and management guidelines, and to establish limits or constraints, which are related to rationally determined environmental objectives.

The District recognizes that it is just beginning to scratch the surface in its attempt to define these environmental constraints on a rational rather than either an arbitrary or an emotional basis. A start has been made, however, and it is our intent to accelerate and expand our efforts in these activities. The District is firmly committed to a policy of maintaining a high quality environment. It also fully recognizes that in the present era of concern with environmental quality the extent to which any water resource program can successfully deliver its water-based benefits is almost wholly dependent on the manner in which it treats the environment. On the other hand, it must be recognized that in spite of the most strenuous efforts in behalf of environmental quality, the present impetus of population growth and the accompanying development in the District area will continue to exert tremendous pressures in the foreseeable future. Some of the pollution problems difficult to come to grips with are those related to the simple occupation of the land by large numbers of people in a modern context. It is not difficult to foresee some very hard choices to be made in the disposal of drainage waters contaminated with various dispersed exotics in periods where water needs are high and water supplies are low.

In the area of institutional constraints the District, as indicated earlier, has concentrated its efforts to date on developing the means to achieve greater flexibility in reservoir operating rules. Aside from this our principle concern at this time is with the body of law and doctrine which relates to individual water rights and the authority of regulatory districts to allocate water and to control its use. Neither individual rights nor agency authority is clearly or adequately defined. At some point in time, hopefully in the near future, a clear and comprehensive water statute must be written. Intelligent and responsive management requires an understandable body of law. The District has not yet addressed itself to the problem of recommending a State-wide water law. Here we are, in a sense, marking time.

SUMMARY

The particular operations and water management responsibilities of the District are by no means unique. There is no question that more complex water management situations obtain in numerous locations elsewhere, nor is it believed that the approach taken to achieve the objective of more responsive and responsible management is necessarily original. However, we believe it to be of interest in terms of its development as a specific response to a particular challenge. There is a unifying concept underlying the several facets of the approach described herein. The challenge facing the District is that of operating a static physical system to serve the dynamic water-based needs of a 16,000 square mile region. The concept underlying the District's response is the belief that its fixed system can be operated effectively in a dynamic situation. With this as a premise the several aspects of the overall approach were logically developed as integrated elements of a total management system.

APPENDIX - REFERENCES

(1) Mitchell, John T., Jr., "A Perspective on the Use of Operation Rules," paper presented at the ASCE National Water Resources Engineering Meeting, Memphis, Tennessee, January 26-30, 1970.

(2) Sinha, Lalit K., "An Operational Watershed Model: Step 1-B; Regulation of Water Levels in the Kissimmee River Basin," paper presented at the Fifth Annual Water Resources Conference, San Antonio, Texas, October 27-30, 1969.

(3) Sinha, Lalit K. and Lindahl, Lennart E., "An Operational Watershed Model: General Considerations, Purposes and Progress," paper presented at the 1970 Annual Meeting of American Society of Agricultural Engineers, Minneapolis, Minnesota, July 7-10, 1970.

(4) Reynolds, John E., "Allocating Water Among Alternative Uses," paper presented at the ASCE Irrigation & Drainage Division Speciality Conference, Austin, Texas, November 5-7, 1969.

(5) Lindahl, L. E. and Hamrick, R. L., "The Potential and Practicality of Watershed Models in Operational Management," paper presented at the ASCE National Water Resources Engineering Meeting, Memphis, Tennessee, January 26-30, 1970.